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Imaginary spaces

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Imaginary Spaces

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i. Abstract

Current three dimensional computer graphics technology has given artists and designers a new set of tools for producing amazingly life-like computer generated images. *Imaginary Spaces* is a series of images which visually depict two unique and imaginative digitally produced environments. By utilizing modern computer graphics technology, these artificial spaces have been brought to life in stunning realism and detail. *Imaginary Spaces* consists of seven total images which showcase each environment from alternating vantage points in virtual space.

ii. Acknowledgements

I would like to take a moment to thank all of the people who helped to make this project a reality. First I would like to thank my family. It was your enduring support that enabled me to complete this great accomplishment. I would next like to thank my faculty advisors. Marla Schweppe, without your help this project would have never made it past the planning stage. Whenever I hit a dead end, you were always there to help get me back on course. Thank you for being such a great teacher, advisor, and friend. Dan Deluna, over the past two years, you have been an invaluable mentor to me. You proved this once again while part of my thesis committee. Without you, I would have never developed the skills and techniques necessary to complete this project. Alex Bitterman, your advice was crucial in how I chose to design the interior elements of this thesis. Thank you for sharing your vast knowledge. Finally, I would next like to thank my great friends and classmates. Roxy Feldman, you were always there with me every step of the way. Thank you for your patience and support. I could have never done it without you. Jen Witkowski, thanks so much for getting my poster printed. It was a great addition to the project. I would also like to say thanks to the entire CGD class of 2007. You could always be counted on for great suggestions and feedback. I am proud to have worked with you all.

I. INTRODUCTION

The most challenging part of this thesis was developing the original concept. By studying books, magazines, and online galleries, I was able to generate many new and diverse ideas. These reference materials related mainly to video game design, high-end 3D computer graphics, and architecture. In addition to design and conceptualization research, I needed to familiarize myself with some advanced practices for creating realistic 3D rendered environments. To accomplish this, I consulted books such as, Advanced Maya Texturing and Lighting, by Lee Lanier and Digital Lighting and Rendering, by Jeremy Birn. Useful web resources included highend3d.com and cgartchitect.com.

In the past, most of my student projects involved building simple 3D scenes. The technical and creative demands of this thesis were far more complex than anything I had previously worked on. Adapting to this new level of complexity required me to develop a more comprehensive understanding of 3D computer graphics technology. By the time that this project had reached completion, my overall knowledge and skill had risen to a whole new level.

A. Technical Overview

Before proceeding, I feel that it is necessary to provide a brief overview of the technology used in creating this thesis. *Imaginary Spaces* was created using Autodesk Maya, which is a high-end 3D computer graphics application. Every observable object in *Imaginary Spaces* was individually built or *modeled* in the computer. Like any object in the real world, a model exists in three dimensions, meaning that it can be rotated and observed from any desired vantage point. Creating a model involves defining the virtual dimensions of an object by constructing a wireframe mesh. This grid of intersecting lines defines the exterior boundaries of a model. Like the shell of an egg, a model has a hollow center and a paper thin exterior.

After a model has been built, color and surfaces details are added during a process called texturing. A texture is a two dimensional image which is wrapped around a model like a skin. Texturing can be compared to the process of peeling an orange and then laying the removed peel flat on a table. Like a texture, the unwrapped peel represents the exact outer surface area of the orange. One could use this unwrapped peel as a reference to specifically place a graphic element on the orange's exterior. After placing artwork over the flattened peel, it can be reapplied to perfectly wrap around the orange's round body.

Like with the orange peel example, texturing a 3D model requires one to first unwrap a model's outer surface area so that any specific graphics can be applied. Once this skin or "texture" receives the intended graphic elements, it will precisely cover the model's exterior surface area when reapplied. Textures not only provide models with color information, but they can also be used to control details such as surface consistency & shininess.

After a model has been textured, virtual light sources are added to a 3D scene. These controllable lights are designed to mimic the way that actual light interacts with objects in the real world. They provide realistic light and shadow effects to objects in a 3D computer graphics scene.

Following the lighting process, a scene is ready to be rendered. At this stage, the computer interprets the scene and generates a detailed visual representation in the form of an image. Rendering is similar to taking a photograph in virtual space. A camera is positioned at a particular angle in three-dimensional space. Like in photography, the computer will produce a visual representation of whatever objects lay in the camera's frame.

II. PLANNING

Following the approval of my thesis proposal, I began the process of planning and conceptualization. This phase of the project was very difficult and time consuming because I did not want to simply mimic a photograph. Instead, my

objective was to develop environments that were truly one of a kind. Planning an entire environment from the ground up proved to be much more complicated than I had anticipated. Designing the physical spaces as well as all of the individual props had to be carefully planned. Maintaining proper design continuity required an intense amount of time and attention. I did not want objects in either environment to appear out of place. To help gain some further insight into interior design, I studied many photographs from architecture and interior design magazines.

My second major planning strategy was to keep a sketch book with me at all times. This allowed me to make a quick visual record of inspirational observations made during my normal daily routine. While sketching, I always tried to make very rough, gestural drawings. This prevented me from duplicating the exact features of an object that I was observing. These vague sketches could later be transformed into a concept that was entirely new. In a few cases, I chose to leave certain objects in this thesis unchanged. The office desk for example, has a design which I have always admired. I grew up with this object and it possesses a certain sentimental quality that I did not want to alter.

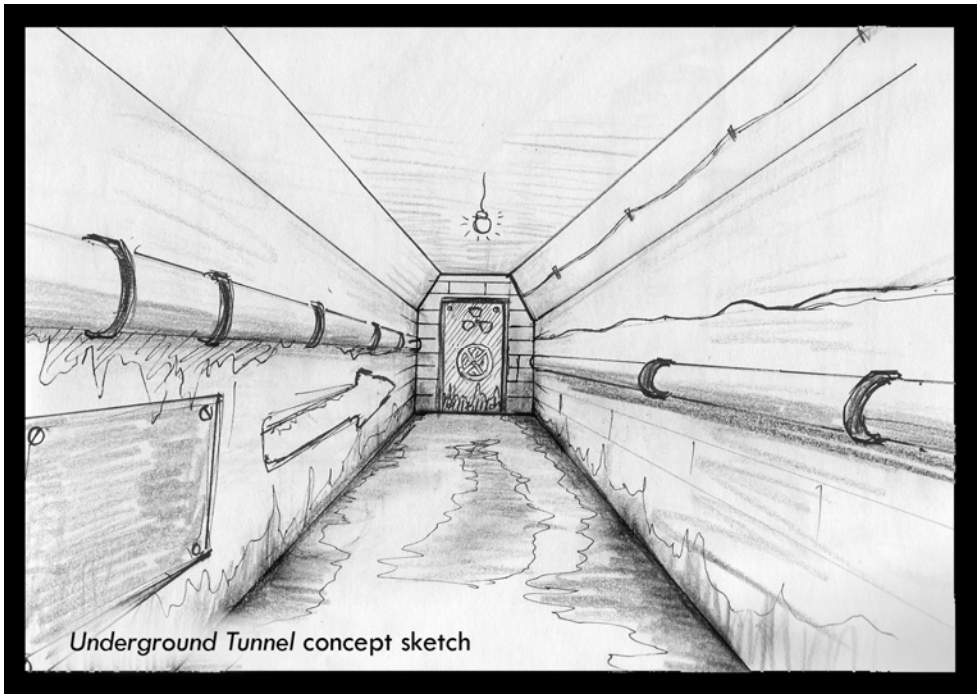

Figure A.

During the planning stage, I created a general list of ideas which I felt had the potential to be great. The ideas from my original list included:

- Classical Ruins
- Outdoor Environment
- Abandoned Underground Tunnel
- An Office
- Science Fiction Inspired Environment

Each of these ideas contains elements of my personality as well as some of my life long interests. I really wanted this project to reflect part of me and maybe even bring elements of my own imagination to life. Unfortunately the short time frame of this project made it impossible to build all of the five environment ideas. After careful thought and consideration, I narrowed my list down to the Office Environment and Abandoned Underground Tunnel. I felt that these two ideas were visually different from one another and would provide this project with a nice variety of environmental elements.

III. DESIGN AND AESTHETIC DECISIONS

A. Abandoned Underground Tunnel

I envisioned the abandoned underground tunnel as a place reminiscent of an old bunker or Cold War fallout shelter. This environment drew influences from certain 3D video game levels which I admired while growing up. The underground tunnel was designed to appear neglected; a place which had not experienced human presence in many years. Some of the original ideas from my design notes include:

- Corroded cement brick walls
- Filthy cement floor
- Peeling paint
- Rusted metal on doors and pipes running along the walls
- Dirt and grime in cracks and along wall borders
- Corroded signs/wall graphics
- Pools of liquid in areas of the floor

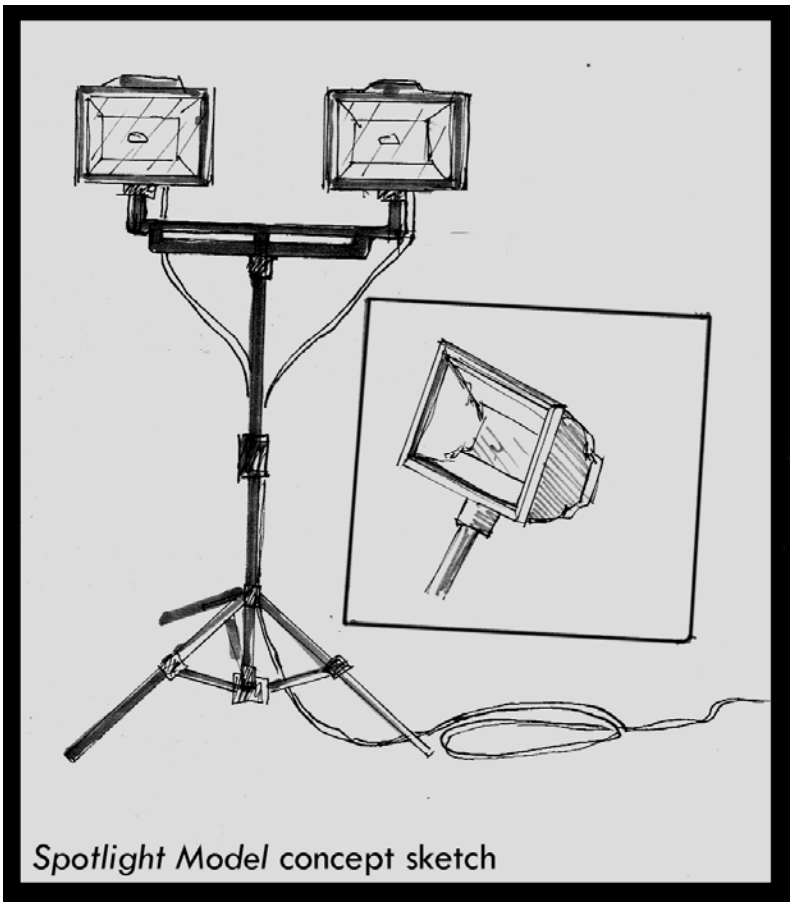

Figure B.

I eventually incorporated additional objects into the tunnel's design. These included rusted metal doors, utility spotlights that could be pivoted, and a second smaller room which could be accessed through one of the metal doors.

To give the tunnel a realistic look and feel, I chose to develop all of the wall, floor, and ceiling textures by hand. Photographs of concrete brick and cement served as the starting point for all environment textures created for the tunnel environment. Experience has taught me that photographs are a great place to begin when trying to create realistic environment textures. After using photographs to build the base textures, dozens of subsequent graphics were introduced and layered above. Photoshop's layer modes were instrumental in creating realistic dirt, stains, and peeling paint effects. This technique allowed these imperfections to appear as if they were actually part of the original brick and concrete. The color of brick and concrete was usually assigned some varying shade of grey. Other details included using a slight

tint of green or yellow to create an appearance of wall and floor stains. In addition to color, textures played an important role in creating surface details such as roughness, wetness, and reflection.

For certain scene props, bright colors were used. This allowed these objects to contrast well with the monochromatic floors and ceilings. The color red was used for the metal doors and pipes because I felt that it would elicit feelings of danger. The utility spotlight models were assigned a bright yellow because I wanted them to look new and clean when compared to the tunnel's concrete floors and ceilings.

In order to develop a strong atmosphere, I chose to incorporate dramatic lighting effects into the tunnel environment. Creating the tunnel's dark and mysterious appearance relied heavily on high contrast lighting. The plan was to project bright pools of light on ceiling and wall areas while maintaining areas of intense shadow on the floors. Two utility lights which I modeled were incorporated to provide additional illumination to areas of interest such as doors and pipes. The image below illustrates the lighting quality of the abandoned underground tunnel environment.

Underground Tunnel final render

Figure C.

B. Office Environment

In the house that I grew up in, there is a space which contains an antique wooden desk. During certain times of the day, sunlight passes through this room's large windows. When this occurs, the entire interior becomes blanketed with interesting patterns of light and shadow. After observing this effect during winter break, I decided to incorporate this effect into the office environment of my thesis.

Unlike the room in my family's home, the office environment of this thesis consists of objects primarily made of wood. These objects include shelves, a floor, window frames, a coffee table, end tables, and chairs. The antique desk is the only object in this thesis which remains entirely original. I actually modeled this object using exact measurements that were taken during winter break.

Figure D.

In terms of overall appearance, the office environment is a visual opposite of the underground tunnel. Unlike its dark counterpart, the office environment was intended to look like it is inhabited. My original vision was that of a clean and bright

space littered with evidence of a human presence. Objects like books, glasses, coffee mugs, and random scattered papers were included to suggest the recent presence of some unknown person.

Some of the objects listed in my original design notes included:

- Wooden chairs
- Coffee table
- Full bookshelf
- Large windows
- Antique wooden desk
- Scattered books and papers
- A banker's lamp
- Wooden floor

To maintain continuity between all of the office's furnishings, I chose to use the antique desk as a design guide for developing all additional furniture. The shelf, chair, table, floor, and window frame models were built to exhibit features similar to those of the desk. These common details can be observed in all of the office environment's furniture, window frames, and floor. Each of elements exhibit the same rounded edges and dark, grainy wood textures. At one point during this project, I realized that the heavy use of wood was becoming somewhat overbearing. To resolve this issue I chose to incorporate a round floor carpet into the environment. This object's green color and rough surface texture helped to balance out all of the office's wood.

To enhance the realism of the office environment, all models were assigned their own custom textures. These textures were built from either stock photography which I purchased, or actual photographs taken with my digital camera. During the planning stage, I always carried my camera and frequently took pictures of many different objects. One day, while researching in the library, I decided to take photographs of some old books that were stacked on the shelves near me. Months later I used these same photographs to texture the office's book models. For the heavily used wood textures, I purchased high resolution stock photographs which were modified for each different model.

From early in planning stage I wanted the office environment to appear

naturally lit. I felt that this fit well with the heavy use of natural wood throughout the environment. The space was designed so that sunlight would enter into the scene from three tall windows on the left wall. As light poured in, uniquely patterned areas of light and shadow interact will all objects in the environment.

Figure E.

C. Changes to Thesis Proposal

Due to time constraints, I was required to make a number of major changes to the original proposal of this thesis. Early in the planning stage I began to realize that if I wanted to achieve the desired level of detail and realism, I would need to remove the Flash based navigation component. The complex nature of my original proposal required a greater amount of time and resources than originally anticipated.

Thankfully, with the aid of my committee members, I was able to devise an alternative to using the originally planned point and click navigation component. The first proposed alternative was to create an animated camera "flythrough" of the environments. A number of tests indicated that the camera flythrough would not be an ideal method of displaying this thesis with maximum detail. As a better alternative,

my thesis chair, Marla Schweppe suggested that I produce a number of high quality color prints. This idea proved to be a terrific solution because it provided a means for displaying all of the environmental detail in high resolution. Furthermore, prints could be generated quickly and did not require the use of a computer or monitor for display purposes. Furthermore, using prints was an ideal means for showcasing all the artistic detail that went into this project.

In its finished form, *Imaginary Spaces* consisted of a total of seven high quality framed prints. This included four images of the underground tunnel and three images of the office scene. Each of the seven images was rendered at a resolution of 1500x1940 pixels. This translated into 5" x 6.5" vertically oriented prints. For the thesis show, the final, framed prints were hung horizontally and arranged so that images from each environment were grouped together. In addition, to the framed prints, I created an 18" x 22" poster which described the project. The image below illustrates the final display configuration of *Imaginary Spaces*.

Figure F. - *please note: the actual final display configuration contained a total of seven horizontally oriented pictures. The above is an illustration.*

A second change that I made to my proposal relates to the environment's design goals. The original plan involved intentionally distorting the environments in

order to achieve a type of forced "perceptual inconsistency". During the planning stages I began to place a greater level of importance on developing complex textures and light setups. I felt that developing these skills were the true focus of my studies at RIT and wanted this project to reflect the best of my abilities as a 3D artist and designer.

With the exception of the above mentioned changes, this thesis followed the originally proposed goal of creating extremely realistic virtual environments which immerse the viewer. By eliminating certain elements from my original proposal, I was able to achieve a level of production quality that would have otherwise been impossible.

IV. UNEXPECTED OBSTACLES

During the course of this project, a number of unexpected technical obstacles had to be dealt with. The greatest problem which I encountered had to do with rendering. By spring quarter, my files were far larger than anything I had previously worked with. Combining such a large number of models, lights, and textures into a single Maya scene drove the required render time through the roof. The Maya file for the office environment eventually became so large that I was forced to separate it into smaller, individual files that could be referenced by a master file.

Another related problem occurred when I attempted to render an image at print resolution. In some cases I had to render each final image in pieces so that they could later be reassembled as a whole. Although successful, this solution was not always reliable and sometimes required me to stay and monitor the computer for up to 24 hours.

By the end of spring quarter I had ironed out all of the major technical issues and completed the project as planned. All of the final rendered images were assembled, color corrected and then sent to the printer. Upon return each of the prints were matted, placed in frames, and packed up in preparation for the 2007 RIT Computer Graphics Design Spring Thesis Show.

V. CONCLUSION

Imaginary Spaces successfully met the goal of presenting a set of realistic and unique virtual environments. At the thesis show, many individuals commented that they at first believed the images were actual photographs. Using color prints as the presentation format for this project proved very successful. They were a terrific means of exhibiting the high level of detail of each environment. This straightforward format allowed individuals from all backgrounds to observe and fully absorb the aesthetic quality of this thesis.

Imaginary Spaces is the culmination of all my graduate school accomplishments. Working on this project taught me a great deal about planning and time management. Without the guidance of my thesis committee members, *Imaginary Spaces* would have never been possible. I firmly believe that this experience has prepared me for success in all of my future computer graphics endeavors.

VI. APPENDIX

A. Thesis Proposal

Project Description

Unlike the physical spaces observed in reality, this project will allow users to explore a world of the impossible; a place absent of logic and reason. The navigable spaces of this unlikely environment will be distinct & unique from one another. The experience in one room may be quite different from that in another. For example, *Room A* may appear dark, damp, and humid whereas *Room B* may be illuminated and seem more sterile. Perception will be intentionally distorted in ways such as exaggerating and varying the scale of objects in relation to the viewers perceived size.

While exploring the spaces, users will have the option of positioning themselves forward and backward, as well as turning left or right. This will be achieved through a simple and intuitive point and click navigation interface. Movement within the environment will be simulated by a system of interchanging, pre rendered images. When a user decides to travel in the forward direction, the current viewed image of the scene becomes replaced by another perspective of the environment which is now ahead of the previous location by perhaps a few feet. The same transitions will occur when a user decides to turn left or right.

Target Audience

The target audience of this project is intended to be any member of the computer literate population. Being strictly a visual experience, this thesis will be culturally

universal; however, an understanding of the English language will be necessary to fully enjoy certain parts of the experience.

A theme of architectural and perceptual inconsistency will be present throughout the entire project. For example, a user exiting a room styled from the Victorian era will unexpectedly transition into a high-tech science fiction inspired area populated by blinking screens and illuminated consoles. Personal items such as written notes & photographs may be scattered through areas. Some objects are intended to give users a feeling that some mysterious individual was recently in that area. An example could be something like observing a partially eaten snack lying on a table or counter. Other special objects in the scene will give users the chance to view outside by looking through certain designated objects such as windows or maybe a telescope. Similarly, users will have the ability to travel "up close" to certain other "unique" objects by clicking on them for a detailed view. These objects of focus are intended to enhance immersion factor as well as help elicit some additional curiosity in the viewer in order to maintain motivation and interest.

To enhance the overall experience, ambient sounds and music will be employed. Music will run throughout the project and environmental sounds will be applied where necessary. For example, an outdoor area might be accompanied by the sound of blowing wind.

Production

All 3D content and environmental detail will be modeled and rendered entirely with Autodesk Maya. Texturing will be done using Maya in conjunction with Adobe Photoshop and possibly ZBrush. Photoshop will be used for the post production cleanup of all rendered images. Adobe Flash will be used for creating a custom navigation interface. This medium will be flexible for handling the exchange of images and interface design components. Furthermore, Flash would potentially allow for the project to be experienced over the web.

Following completing of the main project, a fully animated camera "fly-through" will be rendered and exported to QuickTime. This video will be set up to loop on a

second machine located adjacent to the computer running the main project. Scenes from this animation may be eventually incorporated into the Flash component to serve as an introduction clip or title sequence for the project.

The overall goal of this project is to design and produce a series of very high quality and originally conceived virtual environments. To achieve this, all areas will be carefully lit. High quality image maps will be applied to every object to achieve realistic surface detail throughout the environments. Particles and light effects may be used to build atmosphere and special effects if necessary. Much of the project's navigable space will include organic props such as indoor plants that will be modeled and textured. Atmospheric and nature effects will be incorporated into the outdoor areas as well as indoor spaces if necessary.

To capture the required scene perspectives in Maya, cameras will be placed at pre determined intervals throughout the environment to gather consistent front, behind, left, and right viewing angles. Images will be captured at 90 or 60 degree angles. In some instances, other angles will be taken. It may be possible to key frame or possibly script the changing camera locations so that image sets can be batch rendered. This method will require further research.

For transitions between rooms, animated image sequences may be used. For example, when trying to exit through a door, the user will click on the door to trigger an animation of the door opening followed by the camera moving towards the open door. The clip will then fade/transition to the enter position image of the destination room. Additional testing will be required to determine if Flash can handle this type of animation.

After all of the required CG images have been rendered, touched up, and formatted, they will be imported into a pre-assembled Flash document. Prior to bringing the images into flash, a hand drawn schematic of the virtual spaces will serve as an organizational aid for placing images. This labeled diagram will show where each set of images is to be placed. As shots are imported, they will be crossed off the diagram.

Once in Flash, images will be housed on specific frames inside the timeline. Clicking on a particular region of the screen will jump a user to their desired position by referencing a specific frame's label. Every stored perspective of the environment will have its own labeled frame on the Flash timeline so that it can be easily identified and referenced. Image names and frame labels will remain consistent.

The appearance of pointers will vary depending on the mouse's position over the perspective image. For the user to look left, the mouse will need to be positioned over the left side of the screen. Moving the pointer to this region will cause it to change into a new arrow indicating that a left turn is possible. A pointer's particular change will provide the user with information about what movements are possible from a given location. Custom pointers will be set to swap in and out depending on the mouse's position over the screen.

After all images are imported, an interface will be built around the screen perimeter to contain the scene view area. Certain hints about navigation options will be displayed within a dedicated area incorporated into the interface. There may also be a type of "mini map" embedded within the interface that will allow the user to gauge their current location within the environment. Dimensions of the interface will likely be around 1024x768 pixels. Imported images will be to roughly 2/3 of that area.

If the demands of this project end up exceeding the capacity of Flash, a software package called *Easypano Studio* can serve as an alternative. This visualization tool is capable of producing standalone 360-degree panoramas similar to those of QuickTime VR. Useful additional features include the ability to incorporate smooth animated movements between different panorama locations based on certain mouse actions. Using QTVR will stay reserved as a third backup.

The following elements will require preliminary testing:

a. Animated enter/exit doors sequence.
b. Interface mini map.
c. Flash based image replacement system
d. Changing the display of mouse pointer based on rollover region.
e. Render times with certain lights, particles, materials, etc.

f. Pre-animate camera positions/angles for batch render.

B. Literature Review

Books

Fleming, Bill(1999). Advanced 3D Photorealism Techniques. John Wiley & Sons, Inc.

As the title implies, this book offers many methods for producing 3D content as realistically as possible. Although dated, this book offers a huge array of information related to modeling and texturing. Lessons range from creating natural environments to setting up urban scenes with details such as cracked roads. Despite being 7 years old, this book's concepts still apply to current technology and practice. This book will serve to be very useful for the lesson on creating realistic and tileable textures and incorporating them with a variety of other image maps.

Omernick, Matthew(2004). Creating the Art of the Game. New Riders Publishing.

Creating the Art of the Game brings the reader through every step involved in creating video game content from an artist's perspective. Each of the chapters focus heavily on techniques for advanced modeling, texturing, lighting, and special effects. The book continually reminds the reader that a video game artist's goal is not to just create objects from pixels and polygons, but rather to create and populate entire imagined worlds. Based on this message, the book takes the reader through lessons that are focused primarily on building and populating fantasy worlds. I find that this book will be a very aid for this thesis because it concentrates on techniques for building engaging fantasy spaces and worlds.

Danaher, Simon(2005). Creating 3D Worlds. Cambridge: Alastair International.

This book offers tips and techniques for creating 3D landscapes realistically. It overviews a number of current 3D packages and outlines each of their strengths and weaknesses. Using displacement maps to create terrain elevation and contour is discussed. Although this book is concerned mainly with Cinema 4D, the overall concepts offer helpful insight into modeling 3D outdoor environments. Other useful tips include some approaches to realistic plant modeling and texturing.

Deussen, Oliver & Linterman, Bernard(2005). Digital Design of Nature: Computer Generated Plants and Organics. Springer-Verlag Berlin Heidelberg.

The author offers many techniques for creating realistic organic 3D models such as plants and trees. Chapters are focused primarily on creating realistic content for visualization purposes such as virtual outdoor landscapes, botany, virtual reality, and architecture. As a whole, this book is very technical; however, it does provide insight into the modeling and rendering techniques which work well in producing realistic plants.

Epic Software Group(2003). The Best of 3D Graphics. Rockport Publishers.

This book showcases the top 3D computer graphics of 2003. Each page contains a full color image of a rendered CG image. Information is divided into chapters which each showcase works from within the various sectors of the computer graphics industry. Unlike most of the 3D CG books which are primarily lesson based, The Best of 3D Graphics provides the reader with visual inspiration. Many of the showcased images will be useful in studying and understanding the way in which different professionals go about composing their scenes.

Allen, Isabel(2000). Structure as Design. Rockport Publishers.

Structure as Design is book which provides a visual survey of architectural structures from around the world. Each showcased building is unique in that the most striking design features are also mainly responsible for the structure's overall integrity.

Practically all of the architectural examples contained in this book are completely custom designs. This visual overview will serve as a valuable aid in planning and conceptualizing the architectural environments and spaces of this thesis project.

C. Images

Figure A. p.3
Original sketch if abandoned underground tunnel environment.

Figure B. p.5
This was the concept drawing for the spotlight model which is seen in the underground tunnel environment. This prop's built in lights provide additional illumination to the dark environment.

Figure C. p.7
Final rendered view of the abandoned underground tunnel environment.

Figure D. p.8
A comparison between the original office desk photograph and the 3d modeled version.

Figure E. p.10
A final rendered view of the office environment.

Figure F. p. 11
This image illustrates the how the final frames prints were configured at the 2007 thesis show. Please not that the actual presentation consisted of seven individual frames and not four as seen in this example.

VII. BIBLIOGRAPHY

Books

Allen, Ilabel. Structure as Design. Rockport Publishers. 2004.

Birn, Jeremy. Digital Lighting & Rendering. California: New Riders. 2006.

Danahar, Simon. Creating 3D Worlds. Cambridge: Alastair International. 2005.

Duessen, O. & Linterman, B. Digital Design of Nature: Computer Generated Plants & Organics. Springer Verlag Berlin Heidelberg. 2005.

Epic Software Group. The Best of 3D Graphics. Rockport Publishers. 2003.

Fleming, Bill. Advanced 3D Photorealism Techniques. John Wiley & Sons. 1999.

Lanier, Lee. Advanced Maya Texturing & Lighting. Indiana: Wiley Publishing, Inc. 2006.

Omernick, Matthew. Creating the Art of the Game. New Riders Publishing. 2004.

Websites

CGarchitect.com. 2001-2006. CGarchitect Digital Media Corporation.

CGSociety.com. 2002-2007. The CGSociety.

Highend3D.com. 1996-2006. Highend Network.